Modeling, Simulation and Control of Traffic Flows on a Highway Network

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Introduction

Our research aims at improving the Belgian traffic situation through the development of a flexible testbed environment. By implementing *control measures* and *predicting future traffic conditions* we are able to *resolve congestion* on a highway road network.

A *three-stage plan* is used to obtain our goals : (1) building a traffic flow model, (2) simulating the road network and (3) controling and predicting the future traffic state.

1) Building a Traffic Flow Model

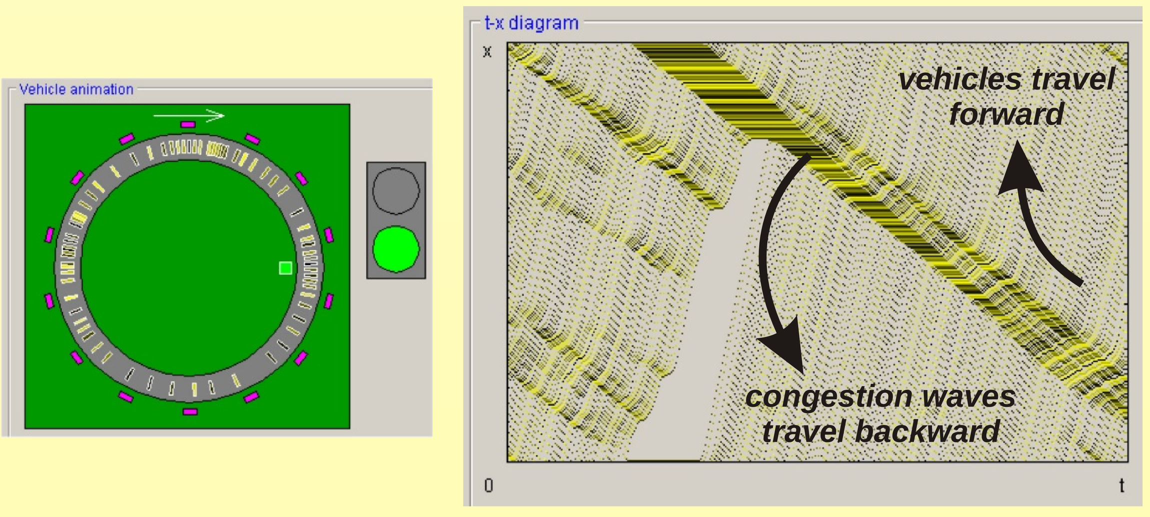
In traffic flow theory, three different classes exist for the modeling phase :

macroscopic models : based on a *fluid-dynamical* analogy, implemented using partial differential equations (large space/time discretizations used).

mesoscopic models : like macroscopic models, but instead based on a *gas-kinetic* analogy.

microscopic models : each vehicle in the traffic stream is considered individually. *Car-following* and *lane-changing* dynamics need to be modeled explicitly (highly computationally intensive).

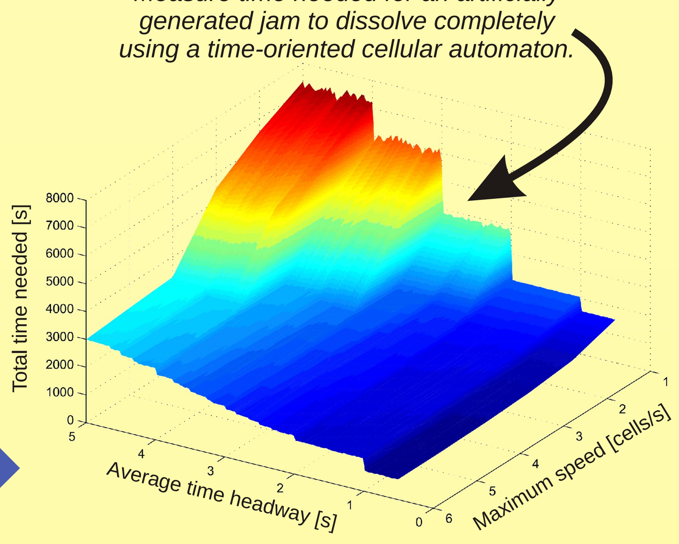
An efficient implementation that is computationally feasible for large-scale networks are ***traffic cellular automata*** *(TCA).*



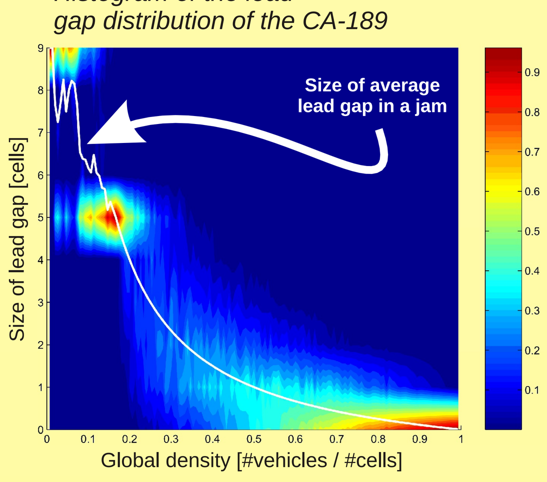
We'll develop a *rule-based* traffic flow model that incorporates the current expertise and solves several classical deficiencies. Car-following and lane-changing dynamics establish the model's core functionality; they both consist of *rule-sets* that describe the system's global behaviour in terms of movements of its individual components.

In order to tune the model for realistic behaviour, *different qualitative measures* can be implemented *for testing purposes*.

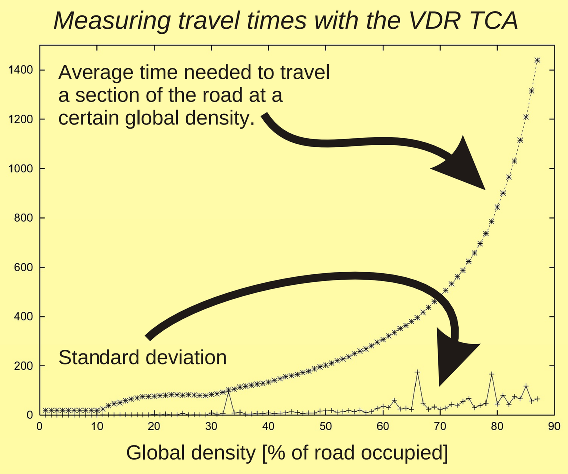
Measure time needed for an artificially generated jam to dissolve completely using a time-oriented cellular automaton.



Histogram of the lead gap distribution of the CA-189

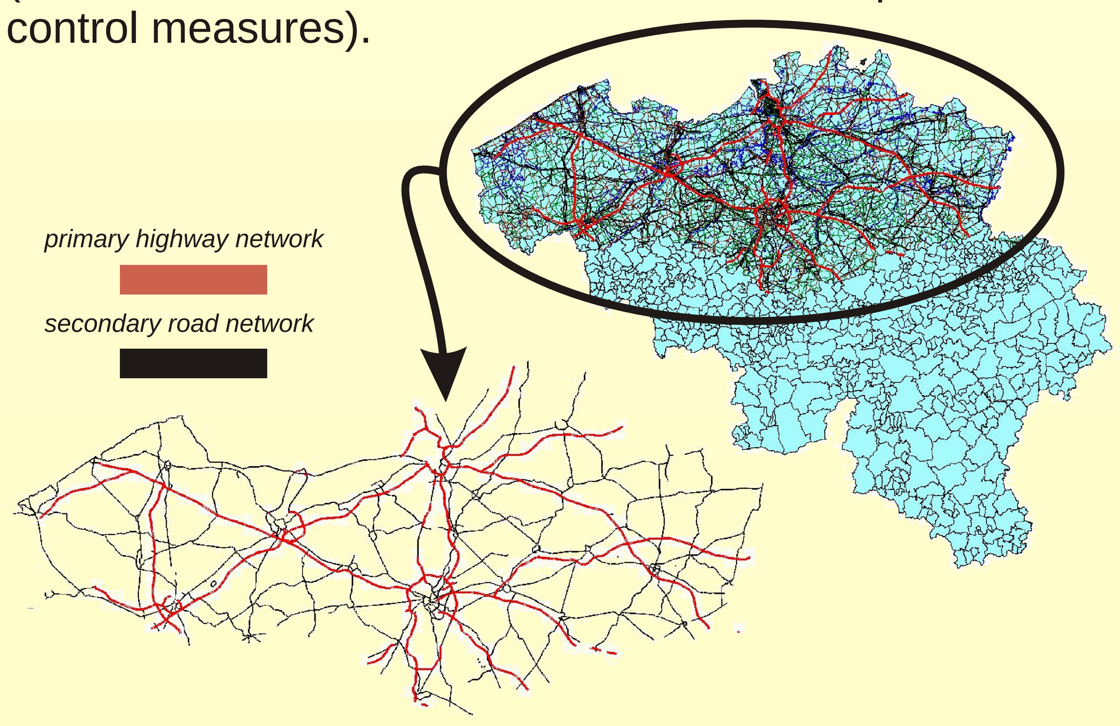


Measuring travel times with the VDR TCA

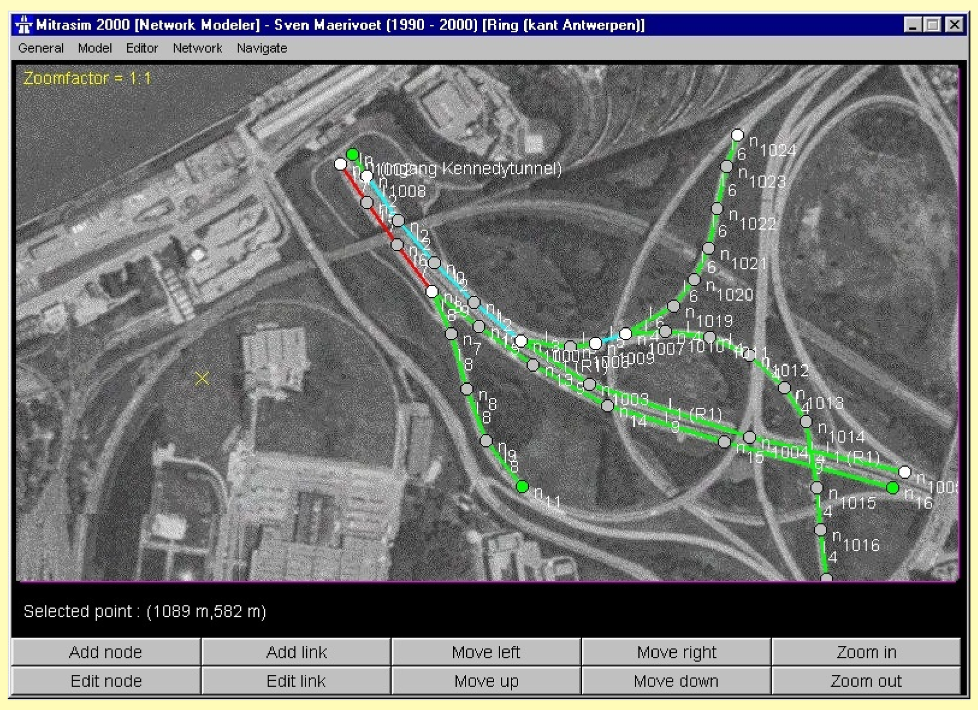


2) Simulating the Road Network

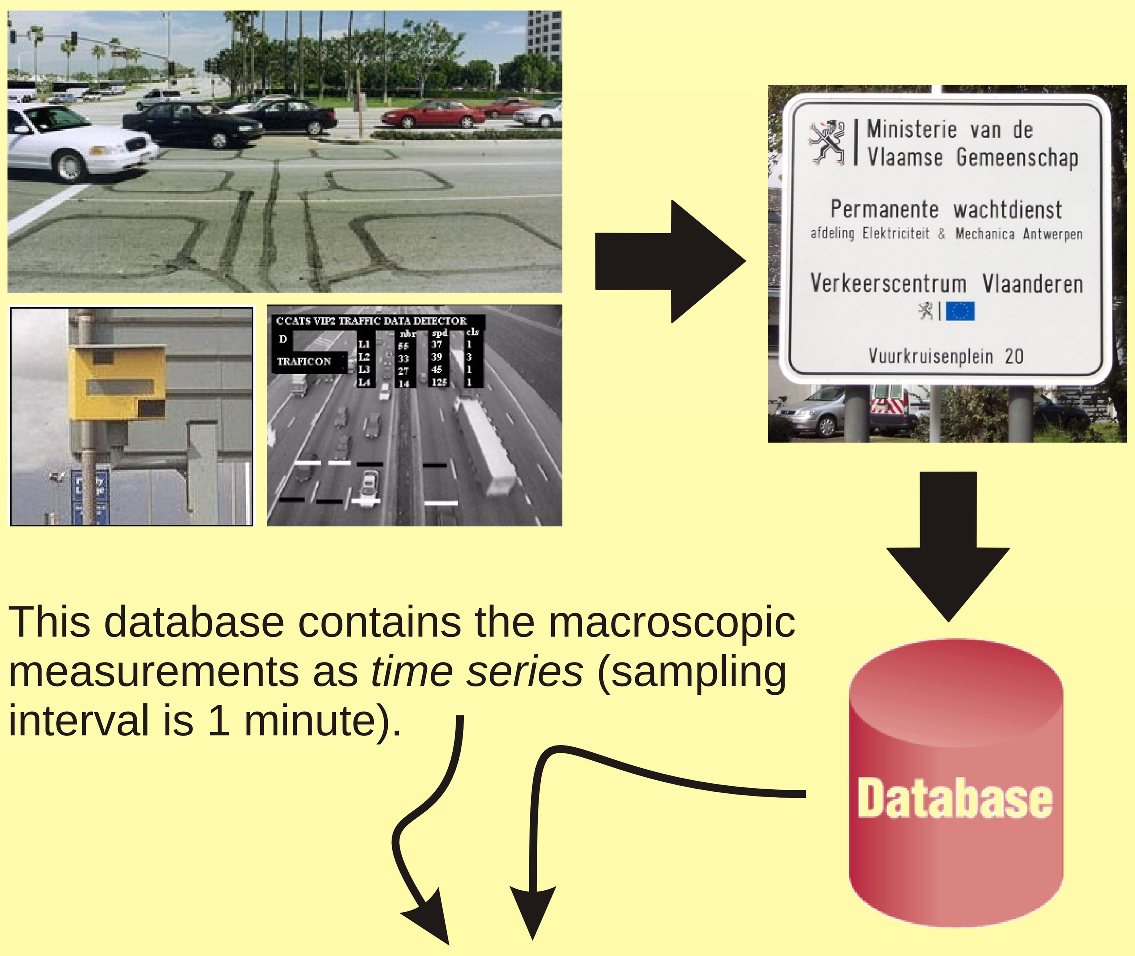
After construction of the cellular automaton, the next step will be to use this traffic flow model in a real-life network environment. The scope is the *Flemish primary highway network*, as well as its *secondary national road network* (which should be considered as a fall-back option for control measures).



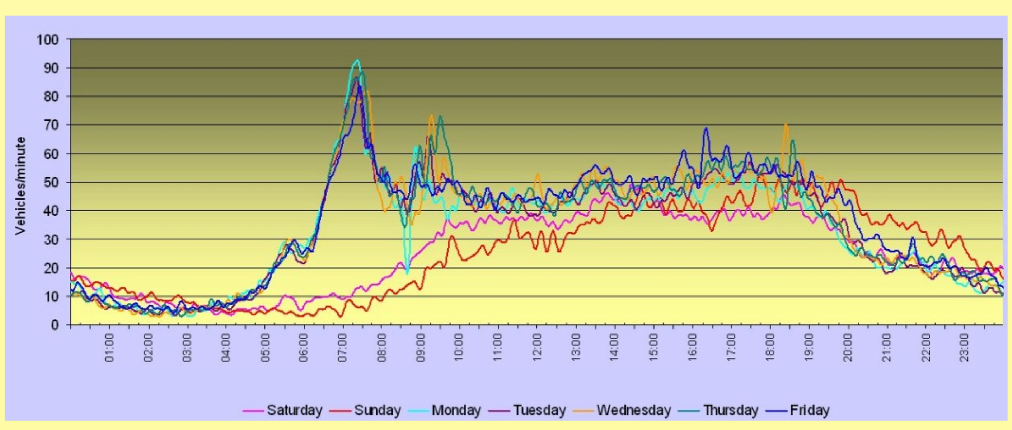
For modeling the road network and in order to have an accurate simulation environment, we'll employ data available from *geographical information systems* (GIS) and gray-scale *satellite images*.



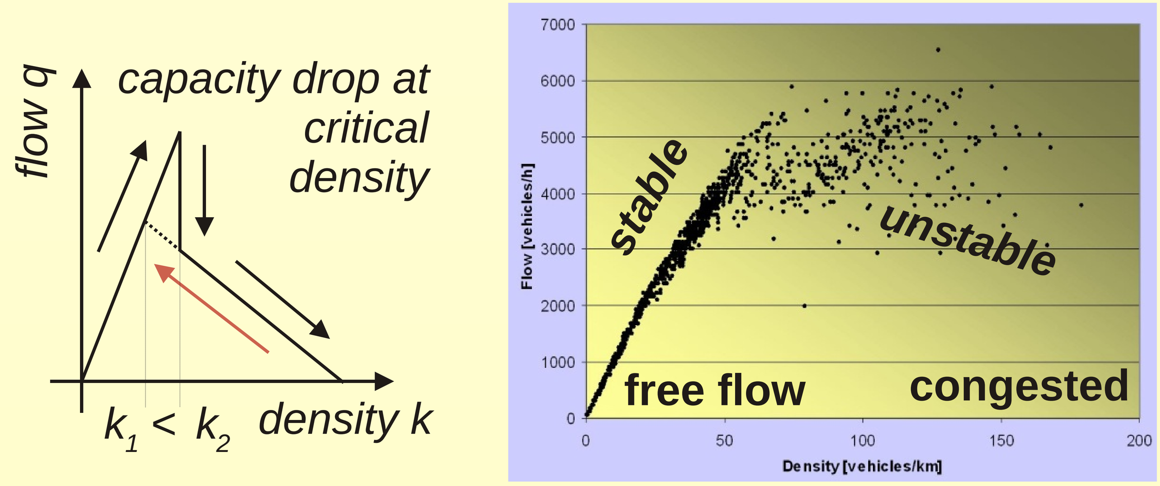
All the traffic data needed for real-time simulation is gathered by sensors in the road network and stored in a database by *Flanders' Traffic Centre*.

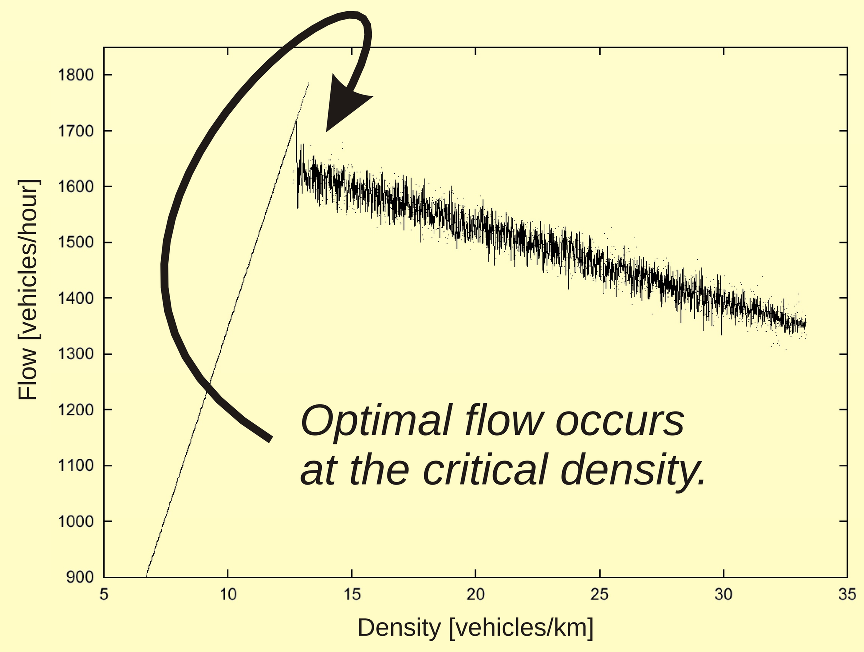


This database contains the macroscopic measurements as *time series* (sampling interval is 1 minute).



From the time series (used in the *calibration* and *validation* of the traffic flow model), we can construct the so-called *fundamental diagrams*. Similar to the real world, our simulation model will exhibit *metastability,* as well as a *hysteresis* phenomenon when traffic is recovering from congestion.





3) Control and Prediction

In order to *guarantee optimal traffic flows*, we'll investigate the use of *traffic control measures* such as ramp metering, variable speed limits, adaptive rerouting, …

Advanced ramp metering can be very effective when implemented using *model predictive control* (MPC).

Prediction of future traffic states is studied using several mathematical techniques, for example :

- the use of (partial) autocorrelations together with historical and actual data,
- model identification, regression techniques, eigen-profile analysis, dedicated datamining techniques,
- spectral analysises of the time series,
- nonlinear modeling techniques (e.g. LS-SVMs),
- attractor reconstruction using embedded delay coordinates, recurrence plots and recurrence quantification analysis,
- correlations with 'external' datasources such as climatological data, road incident statistics, …

Modeling, simulation, control and prediction

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Optimal traffic flows

Our research is funded by the DWTC through the project *"Sustainability Effects of Traffic Management Systems"*.

For more information, please refer to
`http://dwtc-cp40.dyns.cx`

DWTC

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